# MASTER OF SCIENCE
# IN
# OPERATIONS RESEARCH

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**PSYCHOPHYSICAL COMPARISONS IN**
**IMAGE COMPRESSION ALGORITHMS**
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Battlefield commanders are now requesting real-time visual battlefield information. These requests place an enormous strain on current transmission resources due to the file size of the images. As more and more visual information is sent, the ability to compress images efficiently becomes a significant issue. This thesis investigates whether any of the new image compression algorithms (Radiant TIN, Titan ICE, or Low Bit Rate) achieve higher compression ratios than the National Imagery Transmission Format Standard currently used by the Department of Defense. Titan ICE was found to perform better then Radiant TIN; however, the difference is not statistically significant. The Navy already has the proprietary rights to Radiant TIN. Therefore, in the absence of statistical significance, Radiant TIN is the recommended image compression algorithm for future use by the Department of Defense.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Command, Control, and Communications, Computing and Software

**KEYWORDS:** Human Performance, Image Compression

**AN ANALYSIS OF A SATELLITE SURVEILLANCE SYSTEM**
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A new procedure is proposed to evaluate the effectiveness of surveillance satellites in circular orbits. It is assumed that the times of target detections by the satellite are given by a nonhomogeneous Poisson process with detection rate at time $t$ of $r(t) = f(l(t), b_1(t), b_2(t))$, where $l(t)$ is the angular distance between the target and subsatellite point, $b_1(t)$ is great circle bearing from the target to the subsatellite point, and $b_2(t)$ is great circle relative bearing from the subsatellite point to the target. In some circumstances, the dependence of $r(t)$ on $b_1(t)$ and $b_2(t)$ can be ignored, making $r(t)$ only a function of $l(t)$. Then the probability of target detection on a single satellite pass becomes a function of only the minimum angular distance, or lateral range, between the target and subsatellite point. A numerical method using Newton's method is developed for computing the local minima of $l(t)$. Probabilities of detection using this procedure are compared to those computed with existing methods of Wertz and Washburn.

**DoD KEY TECHNOLOGY AREA:** Other (Search and Detection)

**KEYWORDS:** Surveillance Satellite, Lateral Range Curve, Angular Distance, Probability of Detection, Poisson Process

# MASTER OF SCIENCE IN OPERATIONS RESEARCH

## PREDICTING THE PROFICIENCY OF ARABIC AND PERSIAN LINGUISTS TRAINED AT THE DEFENSE LANGUAGE INSTITUTE FOREIGN LANGUAGE CENTER

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The mission of the Defense Language Institute Foreign Language Center (DLIFLC) is to train, sustain, and evaluate foreign language skills of linguists under the guidelines of the Defense Foreign Language Program (DFLP). The DFLP provides the Department of Defense and other federal agencies with linguists capable of supporting United States national interests worldwide. The DLIFLC is responsible for the language training of enlisted and officer personnel of the four armed services and a small number of federal civilians.

Program tests and semester grade point averages (GPAs) evaluate progress within any DLIFLC language program. Satisfactory progress is defined as maintaining at least a C X average in course work. Student success is realized in the student's attainment of minimum proficiency requirements in listening, reading, and speaking skills on the Defense Language Proficiency Test (DLPT).

The purpose of this study is to determine how major program tests, semester GPAs, and cumulative skills GPAs in the Arabic and Persian language departments relate to success on the DLPT. The results of this study will assist the school deans within these language departments in interpreting the meaning of program tests, semester GPAs, and cumulative skills GPAs when making decisions about attrition and academic performance.

The results indicate that the semester GPAs are the most predictive variables of overall DLPT performance for both Arabic and Persian languages.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Language Training, Defense Language Proficiency Test, Program Tests, Semester Grade Point Averages, Cumulative Skills Grade Point Averages

## ESTIMATION OF ANTI-FOULING PAINT THICKNESS AND ITS USE IN EXTENDING THE LIFETIME OF A SHIP'S UNDERWATER HULL COATING SYSTEM

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The underwater hull paint system on an aircraft carrier is comprised of anti-corrosive (AC) and anti-fouling (AF) paint. The AF paint is designed to continuously ablate during the ship's operational cycle, releasing toxins that inhibit marine growth on the hull's surface. In 1997, Whitaker, Wimmer, and Bohlander performed a least squares regression to develop a model that predicts the total coating system wear using dry film thickness (DFT) measurements taken in drydock. The model is derived without use of data taken by remotely operated vehicles (ROV), which measure paint thickness underwater with the potential for variations due to paint swell. An analysis of data taken by ROV is performed here with an attempt made to modify the existing model to include its use. Also, the model has no mechanism to account for the application of additional layers of AF paint at an interim drydock, making it unreasonable to use the model to predict the distribution of paint thickness following two operational cycles with an interim painting. To allow for this prediction, an estimate for the mean thickness of one coat of AF paint is determined. Using this determined estimate and the mean of the predicted distribution for the interim drydock, a simple method is derived for estimating the mean thickness of a hull's total coating system following two operational cycles. This method provides enough information to facilitate deciding in advance how many coats of AF paint to apply at that interim drydock to ensure hull integrity is maintained until the second drydocking evolution.

# MASTER OF SCIENCE IN OPERATIONS RESEARCH

### A PREDICTIVE MODEL OF SURFACE WARFARE OFFICER RETENTION: FACTORS AFFECTING TURNOVER

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Junior Surface Warfare Officer retention is in a crisis. The Surface Warfare Officer community anticipates an inability to fill Department Head billets due to the number of junior Surface Warfare Officers leaving military service. The goal of this study was to predict Surface Warfare Officer retention levels through the validation of a conceptual model from the Surface Warfare Community Manager's Office using logistic regression and Classification and Regression Tree analysis. This study utilized data from the Officer Master File and the results from a questionnaire administered to active duty Surface Warfare Officers. Manpower analysts can use this model to predict whether certain groups of officers, with a given set of characteristics, are more likely to remain in military service.

### AN ECONOMIC ANALYSIS OF RESTRUCTURING UNDERGRADUATE HELICOPTER FLIGHT TRAINING

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The U.S. Navy helicopter fleet is undergoing an unparalleled reduction in the number of different types of helicopters flown. All of the helicopters flown in the Navy are being reduced to two variants; the CH-60S and the SH-60R. A determination of the best way to train the pilots of these two new airframes is desired. Four different training alternatives are developed, specifying various rates of student throughput and various combinations of training aircraft. Each of these alternatives is then applied to two different training plans, which consider the consolidation of different levels of flight training. Aircraft cost data and student throughput requirements are determined through analysis of Navy Visibility and Management of Operating and Support Costs (VAMOSC) data and historical annual training requirements, respectively. Aircraft procurement and operating costs for each alternative are estimated. A ranking of some important benefits of the different alternatives are developed and a complete cost-benefit analysis is conducted. An Additive Weighting and Scaling Model, along with a Hierarchical Multi-attribute Model are used to evaluate the resulting alternatives. The results of this study indicate that under most circumstances the preferred alternative tends to be the one in which the Navy maintains the current training organization.

## DYNAMIC-PROGRAMMING APPROACHES TO SINGLE-AND MULTI-STAGE STOCHASTIC KNAPSACK PROBLEMS FOR PORTFOLIO OPTIMIZATION

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This thesis proposes new methods, based on dynamic programming, for solving certain single-stage and multi-stage integer stochastic knapsack problems. These problems model stochastic portfolio-optimization problems (SPOPs) which assume deterministic unit weight, and normally distributed unit return with known mean and variance for each item type. Given an initial wealth, the objective is to select a portfolio that maximizes the probability of achieving or exceeding a specified final return threshold; the multi-stage problem allows revisions of the portfolio at regular time intervals. An exact method is developed to solve a single-stage SPOP with independence of returns among item types. For a problem from the literature with 11 item types, this method obtains an optimal solution in a fraction of a second on a laptop computer. An approximation method, based on discretization of possible wealth values, is developed to solve a multi-stage SPOP with inter- and intra-stage independence of returns among item types. Running on a desktop computer, this approximation method solves a 3-stage problem with 6 item types in under 12 minutes. With finer discretization in a 3-stage problem with 8 item types, the solution time is about 46 minutes.

**DoD KEY TECHNOLOGY AREA:** Computing and Software

**KEYWORDS:** Dynamic Programming, Stochastic Programming, Knapsack Problem (Single-Stage, Multi-Stage), Portfolio Optimization

## AN ANALYSIS OF THE TACTICAL UNMANNED VEHICLE LIGHT DURING URBAN COMBAT OPERATIONS USING THE JANUS COMBAT MODEL

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The shift of the world's population to the cities has caused the military to increase its focus on urban terrain. The same Tactics, Techniques, and Procedures that are effective on an unconstrained battlefield are not effective in an urban environment. Using technological advances, it may be possible to replace flesh and blood soldiers and marines with metal and plastic surrogates to perform the Reconnaissance, Surveillance, and Target Acquisition mission. Since these unmanned vehicles and the tactics to employ them are still in the concept development phase, they are not widely tested yet for their utility in tactical scenarios. This thesis will examine the detection capability and survivability of a Tactical Unmanned Vehicle Light in an urban environment. The data is generated through multiple combat simulations using the Janus combat model and is analyzed using statistical techniques. The result benefits the Unmanned Ground Vehicle/System Joint Project Office in their acquisition process and both the United States Army and Marine Corps in their development of Tactics, Techniques, and Procedures for employment of unmanned tactical systems in urban warfare.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Electronics, Sensors, Ground Vehicles, Modeling and Simulation

**KEYWORDS:** Janus, Unmanned Ground Vehicles, Urban Combat

## A COMPARATIVE ANALYSIS OF ACTIVE AND PASSIVE SENSORS IN ANTI-AIR WARFARE AREA DEFENSE USING DISCRETE EVENT SIMULATION COMPONENTS

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**Master of Science in Operations Research-March 1999**
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**Thomas W. Lucas, Department of Operations Research**
**Second Reader: Arnold H. Buss, Department of Operations Research**

Anti-air warfare (AAW) has been a top priority for the world's navies in developing tactics and choosing the most effective ship defense systems. Analyses of such extremely complex system behaviors require the utilization of innovative tools that are flexible, scalable, and reusable. This thesis develops a model as an analysis tool to measure the effectiveness of radar and IR sensors in AAW area defense. The model is designed to support reuse, provide easy model configuration, flexibility, and scale changes. A component-based simulation approach was adopted for this model using the JAVA™ programming language to provide the necessary scalability and flexibility. The MODKIT approach was used as the architecture of component designs and the SIMKIT was used for discrete event simulation purposes. In addition, a small combat component library was constructed for future research. To demonstrate the analysis capability of the model a comparative analysis was conducted for radar and IR sensors in AAW area defense. The results of the simulation runs indicate that the model provides a good capability for aiding decision making, including effectiveness analysis, parameter sensitivity analysis, and exploratory analysis.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Battlespace Environments, Conventional Weapons, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Discrete Event Component Based Simulation, Naval Air Area Defense, Radar, Infrared Search and Track Systems

## ITERATIVE ALGORITHMS FOR TWO-PERSON ZERO-SUM GAMES

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In 1951, G.W. Brown proposed an iterative algorithm called "fictitious play" for solving two-person zero-sum games. Although it is an effective method, the fictitious play algorithm converges slowly to the value of the game. Recently, Gass, Zafra, and Qiu proposed a modification that applies to symmetric games, i.e., games with skew-symmetric payoff matrices. To solve non-symmetric games via their modification, the games must be made symmetric via a transformation. Gass, Zafra, and Qiu reported that their modified algorithm converges faster than the original fictitious play on a collection of randomly generated games. However, their results on non-symmetric games only apply to games whose values are near zero. When game values are far away from zero, this thesis empirically shows that the original fictitious play algorithm can outperform the modified one. Gass, Zafra, and Qiu's method is static, in that the symmetric transformation is done once prior to the start of their modified algorithm. However, they suggested the exploration of dynamic methods where the transformation is periodically revised. This thesis proposes and investigates the convergence behavior of one dynamic transformation technique for solving general two-person zero-sum games.

**DoD KEY TECHNOLOGY AREA:** Other (Game Theory)

**KEYWORDS:** Two-Person Zero-Sum Games, Regular Fictitious Play, Modified Fictitious Play, Symmetric Games, Game Value, Randomized Strategies

# MASTER OF SCIENCE IN OPERATIONS RESEARCH

**A MULTI-SERVICE LOCATION-ALLOCATION MODEL FOR MILITARY RECRUITING**
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A mixed integer non-linear program was developed, MS-LOCAL, to help the Department of Defense decide where to locate recruiting stations and how to allocate recruiters to those stations. The goal of MS-LOCAL is to obtain the greatest number of enlisted recruits for the lowest possible cost. MS-LOCAL is solved in two forms: one that minimizes cost subject to production goals (in number of recruits), and a second that maximizes production subject to a budget constraint. MS-LOCAL, is illustrated with data from the Jacksonville, Denver, and Boston metropolitan areas using a production function recently developed for all zip codes in the United States; the production function estimates recruits obtained for given recruiting stations and recruiter allocations. Our results show that a combination of single-service and joint-service stations is most effective in minimizing cost and maximizing production. Compared to the current configurations of stations and recruiters in the metropolitan areas, MS-LOCAL estimates that cost savings of 10-32% or production increases of 2-8% are possible.

**DoD KEY TECHNOLOGY AREA:** Other (Recruiting)

**KEYWORDS:** Optimization, Mixed Integer Programming, Facility Location, Multi-objective Programming, General Algebraic Modeling System (GAMS)

**COMPONENT-BASED SIMULATION OF THE SPACE OPERATIONS**
**VEHICLE AND THE COMMON AERO VEHICLE**
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**Second Reader: LTC Charles H. Shaw, III, Department of Operations Research**

In the ongoing competition between strike platforms and Integrated Air Defense Systems (IADS), strike platforms currently have the upper hand. However, the desire of modern military and political leaders to conduct accurate and effective strike missions on enemy military targets using limited resources, with a minimal risk to U.S. resources and personnel, in a timely manner is in direct competition with an adversary's goal of defending his territory and assets. An adversary can threaten, deter, or even destroy strike assets used to attack him using IADS, aircraft and other means. With fewer overseas bases and increasing demands on the Carrier Battle Groups (CVBGs), it may be necessary to look at new technologies to enable the United States to strike potential opponents in a timely fashion. The Space Operations Vehicle (SOV) is a low earth orbit capable space vehicle being developed by Phillips Laboratories at Kirtland AFB, New Mexico. The SOV will be a cross between the space shuttle and an F-14 fighter, a rugged low earth orbit capable vehicle designed to conduct multiple sorties for military purposes.

This thesis develops a software component architecture and component library for building simulations for analysis of current and proposed military systems such as the SOV. With this software package, proposed and current weapon systems performances can be simulated, tested, evaluated, and adjusted in an iterative process by which analysts can make modifications to the simulation with greater speed, flexibility, and productivity. This software package will support the Simulation Based Acquisition (SBA) process through all the phases and milestones of an appropriation program and help ensure the United States obtains the best equipment to maintain its edge on the battlefield.

This package is ideal for the initial evaluation of concepts and plans and is poised for growth as a comprehensive analysis tool for the entire acquisition process.

**DoD KEY TECHNOLOGY AREA:** Air Vehicles, Space Vehicles, Modeling and Simulation

**KEYWORDS:** Component Based Simulations, Simulation Based Acquisition, Space Operations Vehicle, Common Aero Vehicle, Air Defense Systems, Strike Warfare

**THE EFFECT OF TEXTURE ON DISTANCE ESTIMATION
IN SYNTHETIC ENVIRONMENTS**
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The objective was to determine whether egocentric distance judgments are accurate in a virtual environment with different ground surface textures. Methods were: observers were immersed within a virtual environment consisting of a large L-shaped room with a column located down one corridor and a flagpole located down the other. The observer's task was to view the column, then turn 90 degrees to view the other corridor where the flag was positioned. The observer then moved the flag's position (by using the joystick) until the distance between the observer and the flag was the same as the distance between the observer and the column. The texture beneath the column and the flag was varied from a high-density texture (grass), to medium density (brick), to a low-density texture pattern (carpet). A within-subject design with column size (2 levels), column distance (4 levels), and surface texture (9 levels) was used. The results were that subjects' distance estimates were significantly better when the brick texture was used underneath the column, than when the grass or carpet texture was used. Conclusions: Egocentric distance judgments are very accurate in a virtual environment over a variety of textures when using a perceptual matching task.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Human Systems Interface

**KEYWORDS:** Synthetic Environments, Virtual Environment, Virtual Simulation, Visual Perception

**VISUAL PLANNING AID FOR MOVEMENT OF
GROUND FORCES IN OPERATIONS OTHER THAN WAR**
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Second Reader: Gordon H. Bradley, Department of Operations Research

The fall of the Berlin Wall in 1989 marked the change of the political and military situation worldwide. Peace keeping missions became more likely than major regional conflicts. However, the conventional combat simulations, which were developed for the combat between heavily armored forces could not handle these new situations. In these new missions the movement of ground forces becomes a major task for any commander. This thesis develops a software architecture of loosely coupled software components. These components are combined to simulate the movement of convoys. The simulation is implemented as an event step model. For visualization of the ongoing simulation a different component displays the convoy locations on a geographical display. The combination of both modules allows the analyst to validate a given movement plan and to identify possible weak points and threats.

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Ground Vehicles, Modeling and Simulation

**KEYWORDS:** Operations Other Than War, Peace Keeping, Movement Planning, Convoy, Ground Forces, Simulation, Software Components

## HUMAN FACTORS ANALYSIS AND MODELING OF
## U.S. NAVY AFLOAT ELECTRICAL SHOCK MISHAPS
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### Advisor: CDR John K. Schmidt, School of Aviation Safety
### Second Reader: Lyn R. Whitaker, Department of Operations Research

Electrical shock mishaps account for 33 percent of all personnel injuries occurring onboard U.S. Navy surface combatants from 1995 to 1997. Clearly this indicates a need to identify the root causes and to develop intervention strategies for preventing electrical shock. Electrical shock root causal factors are identified through the evaluation of Special Case Mishap Reports maintained by the Naval Safety Center. Analysis indicates that over 85 percent of electrical shock mishaps are human factors related. Scenario analysis coupled with categorical data analysis is used to identify human factors patterns that are present in electrical shock mishaps. This human factors approach finds that the failure of two primary human factors related interventions identified in the safety literature, improper tagout of equipment and misuse of personal protective equipment, account for 37 percent of the mishaps. A stochastic model of electrical shock mishaps, including human factors related and non-human factors related mishaps, is constructed to develop an overall impression of the status quo. This model is then used to forecast the impact of correcting the identified failed interventions on future expected mishap frequencies and associated costs.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation, Other (Accident Analysis)

**KEYWORDS:** Maritime Mishaps, Electrical Shock, Accident Analysis, Human Factors, Human Error, Accident Classification, Accident Prediction, Poisson Process, Modeling, Cost Estimation

## AN ANALYTICAL MODEL OF MAINTENANCE RELATED INCIDENTS
## FOR NAVAL RESERVE FLEET LOGISTICS SUPPORT SQUADRON AIRCRAFT
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### Robert R. Read, Department of Operations Research
### Second Reader: Lyn R. Whitaker, Department of Operations Research

Although Naval Aviation has dramatically reduced its mishap rate to less than 3 mishaps per 100,000 flying hours, it continues to search for ways to reduce incidents. One way to reduce incidents is to reduce human error, the most prevalent cause of Naval Aviation incidents. In order to meet current goals to reduce incidents, Naval Aviation needs to focus on human errors in maintenance in addition to those in-flight. The potentially disastrous result of a mishap in Naval Reserve Fleet Logistics Support (VR) community has compelled this study. VR community maintenance related mishap, hazard, and injury reports are analyzed to determine trends and patterns and to identify potential interventions. The data from 124 incidents is fit to a homogeneous Poisson process model. Using the Human Factors Analysis Classification System (HFACS) maintenance extension, incident casual factors involving maintenance of VR type aircraft are identified. These causal factors are regarded as areas where intervention strategies can be applied to potentially reduce the likelihood of a mishap. Two initial areas for immediate consideration are contractor incidents and those with procedural violations. Recommendations regarding the implementation of HFACS maintenance extension for use in personnel injury and hazard reports are provided.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Accident Analysis)

**KEYWORDS:** Aviation Mishaps, Aviation Accidents, Aviation Hazard, Personnel Injury, Accident Analysis, Human Factors, Human Error, Accident Classification, Accident Prediction, Poisson Process, Modeling

# MASTER OF SCIENCE IN OPERATIONS RESEARCH

**DEFENSE OF NAVAL TASK FORCES FROM ANTI-SHIP MISSILE ATTACK**
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**Second Reader: Arnold H. Buss, Department of Operations Research**

The quantity, capability, and availability of Anti-Ship Missiles (ASMs) pose a significant threat to the safe operation of United States Naval Forces in the waters off of potentially hostile shores. Potential adversaries continue to improve their ability to attack our ships, requiring that we constantly analyze our defenses against such attacks. Existing computer models and simulations do not provide force commanders or naval analysts with an adequate tool to properly evaluate the threat and the best ways to minimize it. This thesis has developed such an analysis tool, called the Anti-Ship Missile Defense (ASMD) model. It allows for analysis to be performed from an entire task force perspective, modeling the entire process by which ASMs select their targets and the methods by which the defending escorts assign defensive fire. Effective Screen Design and Defensive Firing Policy is a large and complex problem, but exploratory analysis using ASMD has yielded useful insights. In ASMD, moving objects are more fully rendered, featuring smooth acceleration, turning and altitude change features. In support of these complicated moving entities, a highly capable mathematical library was created to solve the resulting equations of motion. The software components and architecture developed for ASMD provide significant flexibility and reuse potential for future analysts.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Sensors, Modeling and Simulation

**KEYWORDS:** Aegis Defense System, Standard Missile, Cruise Missile, Java Simulation System

**A COMPARATIVE ANALYSIS OF SHIP SELF AIR DEFENSE**
**(SSAD) SYSTEMS USING A MODKIT SIMULATION**
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**Thomas W. Lucas, Department of Operations Research**
**Second Reader: Arnold H. Buss, Department of Operations Research**

Rapid changes and developments in defense technology have created a difficult analytical environment for decision authorities when selecting the best weapon system for their armed forces. Appropriate operations analysis techniques and tools can provide some insight needed for the selection process. The objective of this thesis is to identify and develop suitable Operations Research analytical techniques and tools to aid decision authorities in the Ship Self-Air Defense (SSAD) system selection process. The thesis first develops a SSAD system simulation Model (SSAD-Sim) using discrete event simulation techniques and implements it in the Java programming language and Modkit. The simulation is then used to identify appropriate exploratory analysis capabilities including measures of effectiveness evaluation and parameter sensitivity analysis. Exploratory analysis techniques are used to evaluate two different SSAD systems and firing policies. Key parameters analyzed for sensitivity include numbers of trackers, Surface-to-Air Missile (SAM) inventory levels and tracker slew delay. As a result of the success of the SSAD simulation, further component additions and modifications are recommended for further study and development.

**DoD KEY TECHNOLOGY AREAS:** Other (Ship Self Air Defense Systems, Analysis and Modeling)

**KEYWORDS:** Ship Self Air Defense Systems, Surface to Air Missiles, Anti-Ship Missiles, Firing Policies

### EVALUATION OF OPERATOR PERFORMANCE USING TRUE COLOR AND ARTIFICIAL COLOR IN NATURAL SCENE PERCEPTION

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Currently, the two most commonly used night optical devices employed in military operations are the long-wave infra-red sensor and the image intensified sensor. Recent advances in technology have permitted the fusion of the output of these two devices into a single color display that potentially combines the capabilities of both sensors while overcoming their limitations. Although the concept is appealing, previous sensor fusion studies have been inconclusive on the benefits of an artificially colored target. Perhaps, an artificially colored target disrupts an operator's visual processing thereby hindering the detection of a target. The purpose of this thesis is to compare the effects of artificial color, natural color, and monochrome formats in visual scene perception. It is hypothesized that participant response times and error rates would be greater at detecting an artificially colored target compared to a natural colored or a target presented achromatically. Two experiments were conducted. Experiment one used non-degraded imagery and experiment two used degraded imagery to compare these effects. It was found that reaction time and error rates for naturally colored and achromatic images were similar and substantially less when compared to artificially colored images. For degraded scenes, natural color was more beneficial when compared to achromatic and artificially colored scenes. Additionally, artificially colored scenes caused extremely large error rates and reaction times. These results will provide algorithm developers insight into the importance of color constancy.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Human Systems Interface

**KEYWORDS:** Sensor Fusion, Human Factors, Night Vision Devices, Target Recognition, Human Visual System, Natural Scene Perception, Artificial Color, Natural Color

### THE QUICKEST PATH NETWORK INTERDICTION PROBLEM

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A network user selects a route (path) between two known locations, in a road network, to transport a convoy of supplies as quickly as possible. Route selection is complicated by a "time delay" that is a function of a route's capacity and the convoy's size. The problem of allocating limited interdiction resources to damage or destroy network arcs was studied so as to maximize the user's minimum transit time between the locations. This network interdiction problem is solved using special decomposition techniques involving a set-covering master problem and "quickest-path" subproblems. The quickest-path problem, which incorporates arc lengths, measured in time, and a path's time delay, is a generalization extension of the classical shortest-path problem. Problems with up to 196 nodes, 1066 arcs and enough resource to interdict 10 arcs are solved in about 8 minutes on an IBM RS-6000 model 590 workstation. Solution times drop by over 58% when a 10% optimality gap is allowed.

**DoD KEY TECHNOLOGY AREA:** Other (Network Interdiction)

**KEYWORDS:** Network Interdiction, Mathematical Programming, Shortest Path, Maximizing a Shortest Path

**EXTENDING THE STATE-OF-THE-ART FOR
THE COMAN/ATCAL METHODOLOGY**

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**Master of Science in Operations Research-March 1999**
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This thesis reviews currently existing attrition methodologies and critically examines the (ATtrition CALibration) ATCAL approach for heterogeneous force mixes. Lanchester attrition-rate coefficients must be calibrated for use in ATCAL. When the aggregated combat results from a Lanchester-type attrition model agree with the results of a high-resolution simulation, for a particular mix of weapons on either side, the equation is said to be calibrated. Combat scenario runs are made in the high-resolution JANUS combat model. A maximum likelihood estimation approach (COMAN), which incorporates target priority and availability information, is used to estimate the Lanchester attrition rates in the ATCAL model. A continuous-time, three-state Markov chain model of target acquisition in JANUS is used to obtain the target availability parameters required in the COMAN approach. Bootstrap confidence intervals are developed for the attrition-rate estimates and the target availability parameters. The ability of the ATCAL methodology to replay JANUS results in an aggregated, heterogeneous-force replay model is investigated. These developments have the potential for allowing high-resolution simulation results to be extrapolated to a wider spectrum of conditions (e.g., force mixes) than currently possible by virtue of the more detailed nature of the aggregated-replay model involved.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** JANUS, ATCAL, COMAN, MLE, Combat Models, Simulation, Attrition